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The SPES High Power ISOL production target

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Summary. — SPES (Selective Production of Exotic Species) is a facility under construction at INFN-LNL (Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali di Legnaro), aimed to produce intense neutron-rich radioactive ion beams (RIBs). These will be obtained using the ISOL (Isotope Separation On-Line) method, bombarding a uranium carbide target with a proton beam of 40 MeV energy and currents up to 200 μA. The target configuration was designed to obtain a high number of fissions, up to 10^{13} per second, low power deposition and fast release of the produced isotopes. The exotic isotopes generated in the target are ionized, mass separated and re-accelerated by the ALPI superconducting LINAC at energies of 10 AMeV and higher, for masses in the region of $A = 130$ amu, with an expected rate on the secondary target up to 10^9 particles per second. In this work, recent results on the R&D activities regarding the SPES RIB production target-ion source system are reported.

PACS `29.25.Rm` – Sources of radioactive nuclei.
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1. – The SPES facility

In the SPES [1] facility (layout shown in fig. 1), the radioactive ions will be produced with the ISOL [2] technique by means of the proton-induced fission of uranium contained

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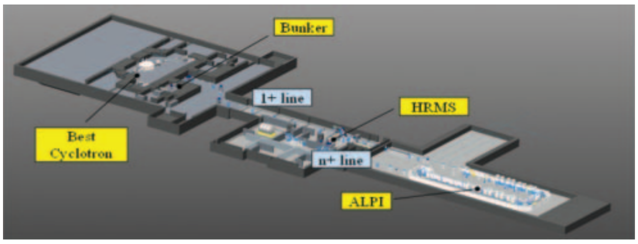

Fig. 1. – The SPES facility, with indication of its main systems.

in the UC_x (uranium dicarbide and residual graphite) [3] direct target and subsequently reaccelerated using the ALPI [4] accelerator complex. The Best C70 cyclotron will be used as a primary proton beam driver, with variable energy (30–70 MeV) and a maximum current of 0.8 mA. In order to reach an in-target fission rate of 10^{13} fissions/s, a proton beam current of 200 μA, 40 MeV energy is necessary. The reaction products are extracted from the target by thermal processes (diffusion-effusion), ionized, mass separated and injected into the re-accelerator. In the SPES facility the first mass selection will be performed by a Wien Filter with a 1/100 mass resolution, installed just after the first electrostatic quadrupole triplet inside the production bunker. The transfer line toward ALPI is equipped with several beam handling systems to purify the beam. In particular, a Beam Cooler and a High Resolution Mass Separator (HRMS) with a 1/20000 mass resolution will be developed and installed. Before the injection in the ALPI superconducting LINAC, the charge state of the beam will be increased by means of a ECR Charge Breeder.

2. – The target - Ion source unit

In an ISOL facility like SPES, the production target coupled with the ion source represents the core of the system. The SPES target is constituted by 7 UC_x and 3 graphite co-axial discs, with diameter and thickness of 40 and 1 mm, respectively. The primary proton beam will be stopped in the target, dissipating its power and generating by fission exotic nuclei in the $80 < A < 160$ mass range. The exotic species will be

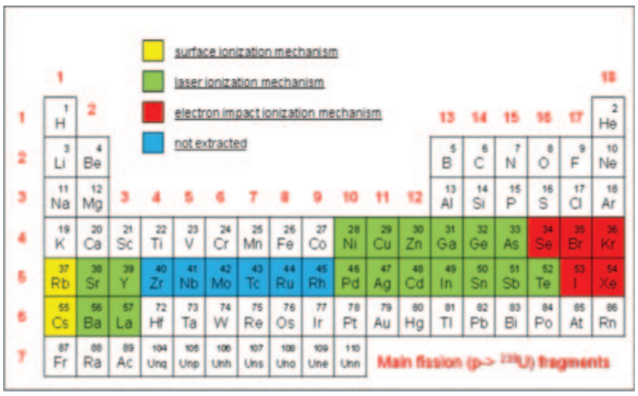

Fig. 2. – Elements produced at SPES with different ionization techniques.

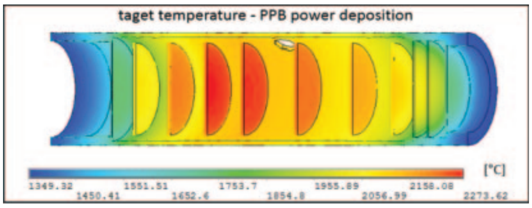

Fig. 3. – Calculated target temperature distribution due to the proton beam power deposition.

extracted from the target, ionized and accelerated to form the RIB. The main elements produced in the fission process are represented in fig. 2, together with an indication of the ionization mechanisms that will be used. Two different types of ion source will be adopted: the SPES surface ion source (SIS) and the SPES plasma ion source (PIS). In the first case, both the surface [5] and the laser [6] ionization mechanisms will be exploited (in the latter, the ion source is named laser ion source, LIS). In the PIS, the fission fragments are ionized according to the electron impact method [7].

In order to gain knowledge of the thermal behavior of the target when impinged by the primary proton beam, its temperature distribution was numerically simulated making use of the FEM (Finite Element Method) software ANSYS®. The power distribution on the target was accurately calculated by means of the Monte Carlo based software FLUKA [1]. Figure 3 represents the target temperature results of the numerical model. It is possible to appreciate that the seven target discs temperature level is generally between 2000 and 2300 °C. The target and ion source unit is contained inside a water cooled, high vacuum aluminum chamber which is connected to the proton and RIB beam lines by means of quick connectors and gate valves.

3. – The target material

The properties required for the SPES target material are related to the efficiency of the release process, which can be divided into two different phases: a) the diffusion of the isotopes, generated inside the material, towards its grains surfaces (governed by Ficks laws), b) the effusion in high vacuum, either in the material pores or in the free spaces surrounding the target discs, towards the ion source. A large number of parameters can favor the fast release of isotopes, both relative to the material properties and to the target operative conditions. The characteristics required for a material to work with a high efficiency as an ISOL target can be summarized as: a) high cross section for the fission reaction, b) ability to work at high temperatures (more than 2000 °C) in high vacuum without degradation of its thermo-mechanical properties, c) sufficient thermal emissivity and conductivity to dissipate the power generated by its interaction with the primary beam without undergoing structural damage, d) high porosity and permeability to the created exotic species. In recent years [3], the synthesis, characterization and on-line test of uranium carbide thin discs (SPES target prototypes) have been successfully carried out, and the production methodology can be considered ready to be used to produce real UC_x targets when SPES will be fully operative.

4. – The target remote handling

The target handling system consists of two independent apparatus, called vertical and horizontal devices that will move the target chamber to and from the on-line zone (bunker). The vertical handling device will access the bunker through a hole on the roof and it will grab the target chamber using an interface tool placed on top of the chamber. On the other hand, the horizontal handling device will access the bunker using a door. In this case, the interface tool is located on the rear of the chamber. Both devices will place and grab the chamber on a coupling table where a series of electro-pneumatic actuators will couple and uncouple the target chamber to the beam lines and open and close the vacuum valves. The horizontal system is constituted of a PLC (Programmable Logical Controller) controlled Automatic Guide Vehicle (AGV) that will move the target chamber to and from the bunker area and a Cartesian handling system, located on the top of the AGV, that will move the target chamber to and from the coupling table once the vehicle is in position. The AGV will be guided automatically by means of an optical system; moreover, manual operation of the AGV by an operator will be available.

5. – Conclusions

SPES is the main nuclear physics project in Italy for the next years. It is an up to date project in the field of Nuclear Physics and in particular in the field of RIBs. The SPES RIB complex will represent also an important step towards the development of the future European project EURISOL [8].

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